Comparison of Sampling, Methods and Versions of AFIS

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Interpretive Summary

High speed measurements are needed to determine fiber properties so appropriate processing decisions can be made to utilize the cottons to their maximum potential and reducing defects. Four distinctly different varieties of cotton were run on AFIS Versions 2 and 4 to determine the best testing conditions, sampling methods and minimum sample size for AFIS. This research studies how to arrive at statistically significant fiber properties from AFIS. Two AFIS systems are compared to each other and to image analysis results of length and circularity to see if one system provides more realistic results than the other. Two sampling techniques are compared to study the impact of sampling on AFIS results, while establishing a minimum sample size. In addition, testing room conditions were also studied. With the properties of individual fibers properly gathered, scientists hope not only to provide the fibers needed for particular processing, but to predict fabric properties from this fiber information. The goal is to use the AFIS data to recommend appropriate processing to improve productivity and minimize yarn and fabric defects.

Abstract

Currently, there are no standards or guidelines for producing statistically significant data using AFIS, the Advanced Fiber Information System. For this study AFIS generates fiber measurements from 5000 individual fibers from each of 25 hand blended slivers. This research addresses key issues, such as sampling techniques, minimum sample size and test conditions and how these effect AFIS measurements. Two versions of AFIS were also compared to each other and to more traditional measurement techniques. The results of the research indicate that humidity affects maturity measurements, under controlled temperature and humidity, sampling is not as critical as for non-controlled testing conditions. In Standard Conditions, using Version 2 the minimum sample should contain at least 75,000 fibers. AFIS Version 4 has better measures of length than AFIS Version 2 due to the new nozzle straightening the fibers. Sample preparation is also very important for maturity measurements, especially IFF and Theta CV from AFIS Version 2. AFIS Version 2's individual fiber immaturity properties, Theta CV, and IFF, have the highest direct correlation to image analysis measurements of white specks. As the Circularity CV and IFF decreased, the white speck decreased. Conversely, as Micronafis increased, white speck decreased. Similarly, IFC is a good indicator of immaturity for AFIS Version 4, and as the ratio of IFC/MFC increases, white speck levels increase. Version 4's IFC and MFC provided the strongest correlation to white specks.

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Introduction

In order to successfully achieve the goal of consistent quality, textile mills require strong, mature, small diameter fibers for their modern processing machinery (Joseph, 1986). Cotton breeders would like to improve fiber quality for better future varieties. Mills need to know what measurable fiber properties are considered the most vital for quality in processing since with each stage of processing fiber properties change (Schneider, 1997). Producers and ginners need to be aware of these fiber properties as well, but often receive contradictory responses from the textile mills where the quality circle began. To meet the demand for fiber properties, AFIS can be used to its full potential by following guidelines outlined in this paper.

Available at SRRC are two versions of AFIS both of which aim to measure properties of single fibers. The main difference between the two versions, Version 2 (V2) and Version 4 (V4), is the one piece nozzle of V4. This new nozzle is more efficient at straightening fibers by removing crimp and hooks, thus improving length measurements. Since the fibers are straightened, less are rejected, thereby increasing the speed of the analysis. A more stable and faster airflow improves fiber measurement. Using different cottons, repeatable results are generated by well maintained, calibrated instrumentation that is run by trained personnel as shown by comparative analysis (Schneider, 1997).

Fiber properties of importance include fiber length, short fiber content, fineness and maturity. Typically, fiber length decreases with each stage of mechanical processing. Yarn neps are usually indicated by low maturity in raw cotton. Spun yarn imperfections are related to short fiber content, maturity, micronaire and sugar content. (Schneider, 1997). Average fineness is classified by micronaire which is not indicative of the content of very immature fibers in the bale, however, the lower the micronaire the higher the probability of dead cotton fibers. In one study, 9000 fibers were used to determine that micronaire less than 2.0 correlates to a diameter of 10 microns. Micronaires of 3.6 to 3.8 correspond to diameters of 10 to 10.3 microns, which are typically unacceptable. According to Backe, AFIS is the only instrumentation that presently comes close to being able to keep the spinner/weaver out of difficulty. Dead cotton should be the focus of research. (Backe, 1996)

AFIS parameters, short fiber content by weight, diameter, trash and neps are used to predict Yankey's count strength product. By the time the fibers reach the chute, strength, elongation, length, length uniformity, micronaire, short fiber content, and neps worsen while trash content improves. At the card fiber properties of strength, elongation and short fiber content are restored to original ginned lint measurements (Ethridge, 1996). Micronaire, maturity, fineness and fluorescence cause 70% of barre defects. Immature fiber content, IFC, corresponds to relative white speck content (Yankey, 1996).

This research studies how to arrive at statistically significant fiber properties data which could be used to produce better yarns and fabrics. Two AFIS systems are compared to each other and to image analysis measurements, such as circularity, and to Fibrograph length measurements to see if one system provides more realistic results than the other. Two sampling techniques are compared to study the impact of sampling on AFIS results, while establishing a minimum sample size. In addition, testing conditions were also studied. With the properties of individual fibers properly gathered, scientists hope not only to provide the fibers needed for particular processing, but to predict fabric properties from this fiber information. The goal is to recommend appropriate processing to avoid the occurrence of fabric defects.

Materials and Methods

Experimental Fibers

Four cotton fiber varieties were used and were grown under irrigated conditions in the same field in the San Joaquin valley in California for this project. Full size production equipment was used throughout the study. The cottons were spindle picked and then ginned at Mesilla Park, NM., followed by two saw-type lint cleaners. Three bales of cotton were produced for each variety. The cottons consisted of two typically rain grown and two irrigated varieties. DP-90 is a commercial Delta Upland fiber, ST-825 is a Mississippi hybrid variety, EA-C30 (experimental - bred to mature early) and EA-C32 (Prema) are Acala cottons. All four cottons were similar in grade and staple length, but varied considerably in fiber strength as shown in Table I.

The cotton was then processed at the USDA, SRRC. A laydown of all three bales was used for each variety. Equal amounts were processed from each of the three bales to make four lots of equal weight per variety. The opening process was the same for all lots: Hopper, Superior Cleaner, two beater sections of the picker and then chute fed to the cards. and were single carded using the Crosrol Mark IV card. The first drawing had eight doublings to 55 gr./yd. and the second drawing had eight doublings to 55 gr./yd. Roving was 1.25 hank with medium soft twist. Both 30/1 and 40/1 yarns with a 3.8 T.M. were spun on a Roberts Arrow, 240 spindle spinning frame with spindle speed of 9500 rpm. 30/1 warp yarns with a 4.2 T.M. were also spun for fabrics with 40/1 filling for all varieties. The ends down tests were run on the 40/1 yarns for 5040 spindle-hours/lot with rounds every fifteen minutes. The ST-825 variety, with its larger perimeter had problems spinning 40/1 so the ends down test for this variety was run using 30/1 yarns. The ginned fiber samples were subjected to Fibrograph, Stelometer, Arealometer, Peyer, microscopic cross sections with image analysis, a complete range of HVI.

AFIS

The Advanced Fiber Information System, AFIS, was developed to rapidly measure essential cotton fiber property distributions such as length, diameter, maturity, fineness, and neps (Shofner, 1990). The instrument acquired for research purposes at SRRC was supplied with the necessary software to run fineness and maturity. The F&M (fineness and maturity) module is now available in the production models of AFIS. The basic hardware is essentially the same for Nep analyses and for F&M and L&D (Length & Diameter) measurements.

AFIS V-2 was used to compare the conditioned and non-conditioned labs. The non-conditioned analysis was performed in a lab with general office conditions of 68°F - 72°F and 53% RH - 72% RH using 7 replications. Each of the replications consisted of 25,000 fibers for a total of 175,000 fibers. Noting that the data leveled off in all cases at 125,000 fibers in the unconditioned lab, a total of 125,000 fibers for each variety were analyzed in a lab with standard test conditions of 70°F +/-2°F and 65% RH +/-2% RH. This consisted of 25 replications each containing 5000 fibers. The conditioned lab study was also used to determine AFIS minimum sample size.

Two sampling methods were compared. Three large samples were taken from each bale, from the top, bottom, and side. The first sampling technique is referred to as the Blended Sample. A large random tuft of cotton (60 to 100 grams) was taken from each of the three locations, then hand blended and sent to AFIS testing. The AFIS operator formed slivers with a density of 10 mg per centimeter, each sliver was approximately 28 cm long. Sixty slivers of about 280 mg and 28 cm in length were prepared. The remainder of the Blended Sample was not used. For the samples noted as the Three Bale Sample the AFIS operator took ten pinches (approximately 2 grams each) of fiber from each of the bags marked Top, Bottom and Side. The fiber labeled Top would be emptied on the counter and each of the ten samples would be taken from distinctly different locations. The same method was used for Bottom and Side sampling and then the 30 pinches were blended by hand and formed into 60 slivers of about 280 mg and 28 cm in length.

AFIS nep test were also run on each system. Ten samples were prepared from each of the bags marked Top, Bottom and Side for each variety for each AFIS system. A 0.5 gram sample is stretched out to about 30 cm. The fibers must be handled as little as possible when preparing the sliver for the nep test, so no neps are generated or destroyed. This resulted in 15 grams of fiber per variety for each AFIS System.

Fabric Dyeing

The fabric is finished with a 0.1% Prechem 70, 0.3% T.S.P.P. boiloff, a caustic scour of 1.1% Prechem SN, 1.1% Mayquest 80, 0.1% Prechem 70 and 0.7% Sodium Hydroxide (Caustic Soda), followed by the same boiloff procedure. The fabric was then bleached (0.1% Prechem 70, 0.5% Mayquest BLE and 3.0% Peroxide (Albone 35)) followed by an acid sour (0.1% Acetic Acid) and dyed with 2% Cibacron Navy F-G Blue, 0.5% Calgon, 8% Sodium Chloride, 0.8% $Na_2 Co_3$ (soda ash) and 0.5% Triton Tx-100. This dye has a high propensity for highlighting white specks in finished fabrics.

Image Analysis

Image analysis was done by the Optimas 5.2 system on a Gateway 2000 P5-120 computer complete with a dual monitor set up with a Sony Trinitron RGB Monitor. A Microimage Video Systems RGB/YC/NTSC color camera was used to extract the image and was placed approximately 18 inches above the fabric sample. Four tungsten 120 V, 300 W flood photography lights were used for better uniformity of the lighting on the fabric. Using the Percent Areas and data collection macros, the ratio of the white speck area to the sampling area, or the % white, and the number of specks are detected. The black and white configuration was enabled to perform the fabric analysis. A calibration was done to ensure the correct sample area was being used and area covered was sequential.

Prior to testing, the operator determined the camera settings, lighting conditions, and programmed the threshold that provided the most realistic representation of the fabric that was undergoing evaluation. To ensure that white specks were being detected properly, the threshold was set using several samples areas from the fabric and remained the same for the duration of the testing of that particular variety. The threshold dictated what was detected as white and thus contributed to the % white of the sampled area. Once the parameters were set, the equipment was then allowed to equilibrate for about one hour. The parameters were set only once and all tests were performed consecutively under the same conditions so that reliable comparisons and correlations could be formulated. The operator manipulated the fabric sample so the same area was not tested more than once and area covered was sequential.

Results and Discussion

Characteristics of Four Varieties

Table 1 shows the properties of the four variety fibers from more traditional measurements from the Arealometer, and Stelometer. The Acalas were generally long, strong, small perimeter fibers. The DP-90 was a medium length, strength, and perimeter fiber. The ST-825 was coarser, slightly shorter, and was similar in cell wall thickness of the EA-C32 and the DP-90. Figure 1 is a representation of the cross section of fibers typical of these varieties. The EA-C30, developed from a breeding program to mature at an early date, resulted in a 20% thicker cell wall as compared with the EA-C32 and this can be seen in the cell wall thickness as compared with the EA-C32. The thicker cell wall also results in EA-C30 being more circular than the other Acala cotton. The STV-825 is the least circular. Micronaire readings show the Acalas at opposite ends of the spectrum with the EA-C30 also having the highest value and the EA-C32, the lowest. The ST-825 has a slightly higher micronaire than the EA-C32 while the DP-90 has an even higher value.

Effect of Room Conditions on AFIS Measurements

Historically SRRC's AFIS Version 2 was run in a non-conditioned laboratory, so we used it to test the effect of room conditions. This data shows that humidity does effects maturity measurements. For all varieties but EA-C30, the V2 IFF (Immature Fiber Fraction) values were higher for the non-conditioned samples than for the conditioned samples, Figure 2. Similar results were seen with the V2 Theta (Circularity) values, with non-conditioned samples being less for all varieties except EA-C30, Figure-3. However, for Area (n), there was no significant difference between conditioned and non-conditioned samples for all varieties, Figure 4. In Figures 2, 3, and 4, the open circles refer to the non-conditioned samples while the filled squares refer to the conditioned samples.

Effect of Sample Preparation

The three bale sampling method was better than the blended bale sampling method for distinguishing the difference between varieties for Version 2's IFF and Theta CV, coefficient of variation of circularity, values using 125,000 sample size. As seen in Figure 5, for the blended bale, all varieties except EA-C30 converge, while for the three bale sampling technique the varieties have distinct IFF values.

Minimum Sample Size

In standard conditions, 125,000 fibers were tested per variety for each AFIS system. For AFIS Version 2, even the most variable parameter, IFF, the weighted average levels off at approximately 75,000 fibers. For AFIS Version 4, IFC (Immature Fiber Content) also showed the weighted average levels off at approximately 75,000 fibers. For both systems 15 replicates of 5000 fibers analyzed with an Alpha of 5% and a Beta of 25% have a 95% confidence that the data is significantly different at one standard deviation and a 25% probability of being wrong if the data isn't shown to be significantly different. For research purposes this should be considered the minimum sample size required for maturity data on this system. For general purposes ± ½ standard deviation from the average of 25 reps should sufficient (40,000 fibers for V2 and 50,000 fibers for V4).

In Figures 6 and 8, the individual replications averaged over 5000 fibers show the variability of the varieties using AFIS V2 and V4 respectively. Figures 7 and 9 demonstrate that as each replication of 5000 fibers is averaged, the graph levels off by 15 replications, or 75,000 fibers for both AFIS V2 and V4.

Comparison of AFIS Systems

Comparing the two AFIS versions, V2 discards approximately 50-80% of fibers due to hooks and crimp. AFIS V4 is more appropriate to measure fiber length properties due to the improved airflow and nozzle removing crimp and hooks. Since V4 rejects fewer fibers the test takes less time to run than V2. L(w), mean length by weight and L(n), mean length by number, measurements for both versions of AFIS have good correlation to Fibrograph data, Figure 10. AFIS V4 shows a slightly longer length for the long fibers due to its ability to straighten the fibers better than V2. Circularity is different for the two versions of AFIS because of the calibration of each system. Both versions show good relationships to circularity as measured by image analysis of fibers, Figure 11. AFIS V2 Neps/Gram data shows some correlation (R^2 = 0.498) to Image Analysis Percent White on dyed fabrics whereas V4 has no correlation (R^2 = 0.007)as shown in Figure 12. Conversely, AFIS V4 Neps/Gram data shows some correlation to Image Analysis White Speck Count on dyed fabrics whereas V2 has no correlation Figure 13. From image analysis studies of white specks, we know that not only the number of white specks is important, but size is also a factor. Percent white takes both of these factors into consideration, which indicates that the V2 AFIS Neps/Gram data is more meaningful in the evaluation of white specks.

Prediction of Fabric White Speck Content

The white speck content of the fabrics is shown in Table 2. For V2, as IFF and Theta CV increase, the percent white on the fabric also increases. Conversely, as Micronafis increased the percent white decreased for AFIS V2. When using AFIS fiber properties to predict fabric white speck content, the individual fiber immaturity properties, Theta CV, IFF and Micronafis, have the highest direct correlation to image analysis measurement of white specks for V2, Figure 14. The equations from multiple regression of Theta CV and IFF to % White, result in an R^2 of 0.731 using 8 replicates of 5000 fibers, and an R^2 of 0.730 using 25 replicates of 5000 fibers, Figure 16. Figure 15 shows AFIS V4 fiber properties Immature Fiber Content (IFC) and Mature Fiber Content (MFC). As the IFC decreases, the fabric percent white also decreases, conversely, as the MFC increases, so does the fabric percent white. The AFIS V4 parameters IFC and MFC are shown to correlate with fabric % White. For AFIS V4, the equations from multiple regression of IFC and MFC to % White, result in an R^2 of 0.816 using 10 replicates of 5000 fibers, and an R^2 of 0.817 using 25 replicates of 5000 fibers, Figure 16.

Conclusions

AFIS V4 is more appropriate to measure fiber length properties due to the improved airflow and nozzle removing crimp and hooks. Circularity is different for the two versions of AFIS because of the calibration of each system. Both versions show good relationships to circularity as measured by image analysis of fibers and good correlations of length measurements to Fibrograph data. When performing tests with AFIS, standard room conditions are important, particularly for maturity measurements, and should be used. Sample preparation is another key issue. By pulling fibers from three different locations on the bale, a more representative cross section of fibers is selected for testing making varietal differences more distinct. With standard conditions, and sampling from three locations, the minimum sample size should be at least 40,000 fibers for V2 and 50,000 fibers for V4; for statistically accurate data for research purposes, 75,000 fibers is recommended. Using V2 data to predict white speck, the fiber properties IFF and Theta CV are important. For V4, the IFC to MFC values are the best predictors of white speck. The particular samples used in this study are distinctly different and therefore, the AFIS values which were found to have good correlations to the white speck defect for these varieties, should be good indicators of the immaturity problem which results in white specks. More varieties need to be studied to validate this work. Future research will be done on thirty one varieties of cotton, twenty-six from the Leading Variety Study by AMS and five varieties with a wide range of fiber properties, subjected to identical conditions from planting through gin processing.

When trying to predict fabric white speck content, immaturity seems to be the key. Currently, industry may only minimize the problem through processing protocols. Hopefully, future research will lead to breeding programs and farming practices that will lower the level of immature fiber in cotton crops. AFIS V4 IFC and MFC values seem to be promising tools which could be employed to improve the white speck content of dyed fabrics.

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